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Title

LOW COST POWER SEMICONDUCTOR MODULE WITHOUT SUBSTRATE

PRIORITY STATEMENT

5 This application relates and claims priority to a
United States provisional application, Ser. No.
60/175,802, entitled Low Cost Power Semiconductor Module
Without Substrate, filed in the United States Patent and
Trademark Office on January 12, 2000.

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BACKGROUND OF THE INVENTION

15 This invention relates to power modules and more
specifically relates to a low cost 3 phase inverter
module which has no substrate for the power semiconductor
die.

SUMMARY OF THE INVENTION

20 Power semiconductor modules are well known and are
widely used. Typically, a plurality of semiconductor
die, such as MOSgated devices, thyristors or diodes in
various combinations are mounted on a substrate heatsink,
such as an IMS (insulated metal substrate) or other
substrate and are electrically connected through the
substrate, and/or by wire bonds, to form a particular
circuit. A printed circuit board containing low power
control components is also supported by the module.
Power and control terminals may then extend from an
insulation housing which carries the substrate.

Substrates used to carry the power die constitute a significant part of the cost of power modules, and therefore they are limited to the smallest possible area. It would be desirable to reduce the cost of such modules while permitting appropriate thermal management and electrical insulation.

SUMMARY OF THE INVENTION

In accordance with the invention, the power die are mounted directly on lead frame extensions of a lead frame which is insert molded within and supported by the module insulation housing. A heat conductive insulation layer underlies the lead frame elements to insulate it from a heat sink support for the module. No added IMS or other substrate is used, thus reducing the cost of the module.

In a preferred embodiment, the module is a three phase inverter circuit for automotive application for example, for electric power steering motors. However, any other desired circuit can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a top view of a lead frame which can be used with the present invention.

Figure 2 is a cross-section of the lead frame of figure 1 taken across section line 2-2 in Figure 1.

Figure 3 is a perspective view of the module of the invention, before its interior is sealed with insulation plastic.

Figure 4 is another perspective view of the module of the invention after its interior is filled.

Figure 5 is a top view of the module of Figure 4.

Figure 6 is a side view of Figure 5.

Figure 7 is an end view of Figure 5.

Figure 8 is a circuit diagram of an exemplary module
circuit which can be formed by the module.

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DETAILED DESCRIPTION OF THE DRAWINGS

Referring first to Figure 8, there is shown an exemplary electrical circuit diagram of a 3 phase inverter circuit which could have application to automotive uses particularly to electric power steering. Thus, terminals 20 and 21 are d-c terminals which could be connected to the automobile battery and output terminals U, V and W are 3 phase output terminals which can be used to power ac motors, or dc motors, such as dc brushless motors, that are typically found within the automotive system. A conventional three phase inverter circuit is shown, using power MOSFETS S1 to S6 in a conventional sequence. The instant invention is particularly suited for low voltage applications. The die of the present invention are rated from 30 to 75 volts and are size 4.0 to 6 die as sold by the International Rectifier Corporation.

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The circuit of Figure 1 is commonly formed by employing unpackaged MOSFET die which are mounted on a substrate and interconnected through the substrate and by wire bonds. The substrate is then mounted within an insulation housing and the terminals 20, 21, U, V, W and G₁ to G₆ extend beyond the housing surface to be available for connection. A printed circuit board will

also be provided to carry an ASIC 22 and other control circuit components.

The substrate used to mount the die within the housing is expensive. In accordance with the invention, 5 this substrate is eliminated, with the die mounted directly on the lead frame extensions of the terminals. Note that any circuit other than an inverter can be formed, and that any type of die or mix of die, such as IGBTs, diodes, thyristors and the like can be used and 10 enjoy the benefits of the invention.

Figures 1 to 7 show a preferred embodiment of the invention for housing the 3 phase inverter circuit of Figure 8. Note that the same identifying numeral or letter is used in all drawings to identify the same part.

Figure 1 shows a lead frame which can be used with 15 the invention. Thus, one half of the lead frame provides terminals U, V and W which are connected to large pad areas 30, 31 and 32 respectively. These pads 30, 31 and 32 will receive the MOSFET die S4, S5 and S6 respectively. The other half of the lead frame has 20 terminals 20 and 21 and a common drain pad 33. Terminal 21 is also connected to a source pad area 34. Die S1, S2 and S3 are connected to pad 33. Die S1 to S6 are vertical conduction die having metallized bottom drain electrodes and a top source and gate electrode. The 25 bottom drain electrodes may be soldered or otherwise connected, as by a conductive epoxy, to the enlarged lead frame pad regions.

After the die S1 to S6 are fixed in place, they may be wire bonded, as shown in Figure 3 to complete the circuit of Figure 8. Thus, as shown in Figure 3, source bond wires connect the pads 30, 31 and 32 to the source electrodes of die S1, S2 and S3 respectively; and source bond wires connect the source electrodes of die S1, S2 and S3 respectively; and source bond wires connect the source electrodes of die S4, S5 and S6 to pad 34 and d-c terminal 21. Note that these bonds can be made after encapsulation of the lead frame in its housing.

Thus, after the die S1 to S6 are bonded to their various pads, the lead frame is insert molded in an insulation housing 50 by a conventional molding operation and the lead frame bridging sections (exterior of the dotted line in Figure 1) are removed to separate the pads from one another. The lead frame is secured within the housing with conductors U, V, W, 20 and 21 extending beyond the periphery of housing 50. Housing 50 may be a QUESTRA plastic made by DOW chemical, a suitable PPA such as the one made by Amoco and sold under the mark AMODEL.

Housing 50 will have windows 51, 52, 53 and 54 to expose the top surfaces of pads 32, 31, 30 and 33 respectively to provide access to die S1 to S6 for the die bonding operation. A rim 60 surrounds the housing 50 and bolt-down openings 61, 62, 63, 64 are provided at the housing corners. A bottom layer 70 of a thermally conductive insulation material is provided to electrically isolate the pads 30, 31, 32, 33 and 34 from one another and from the users heat sink on which the housing is mounted. Note that lead frame pads remove to

ambient all thermal energy generated by the die S1 to S6 through the lead terminals and the thermally conductive insulation layer, which may be placed in contact with a heat sink.

5 As next shown in Figure 3, 4 and 5 printed circuit boards 80 and 81 which carry control terminals G1 to G6 and related Kelvin (source) terminals and wire bond terminals therefor are fixed to the top opposite platform end surfaces of the housing 50 and wire bonds are made.

10 After all wire bonds are made, the interior of rim 60 of housing 50 may be filled by a suitable silastic 90 (Figures 4 and 5), an epoxy or the like.

15 Note that the module of Figures 1 to 7 has no separate substrate for receiving the die S1 to S6 and, therefore has a reduced expense.

20 Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.